Geology, household formation rules and the demand for sons in Vietnam

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Abstract

This paper examines the geological origins of household formation and inheritance rules in Vietnam, and how these influence the contemporary demand for sons. Districts in Vietnam with land more suitable for intensive farming are shown to have both greater density of livestock and to be missing more females under 5 in 2009. The impact of male first-borns on fertility and under-5 mortality is then compared both across patrilocal and matrilocal ethnicities, and across geological areas of Vietnam. The results suggest that the relative value placed on female versus male children is arbitrated by norms regarding household formation and inheritance, which derive partly from geological suitability for plough agriculture.

JEL codes: H4, J1

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1 Introduction

The importance of social norms to economic behaviour is by now widely recognized. Alesina, Giuliano, and Nunn (2013) show that the ethnic origins of parents have important impacts on labor force participation amongst daughters of immigrants to the US. Giuliano (2007), and Fernandez and Fogli (2009) document how beliefs and culture impact living arrangements and female labor force participation, respectively. Fisman and Miguel (2007) show that United Nations diplomats from more corrupt countries accrued more unpaid parking violations in Manhattan. La Ferrara (2003) shows that matrilineal groups in Ghana, but not patrilineal, engage in inter-vivo strategic land transfers to circumvent traditional inheritance rules. This paper examines the geological origins of the household formation and inheritance rules which determine son preference. The insights of Boserup (1970) are employed to develop a simple model of family farming in which male and female labor are gross substitutes. Improvements in farming technology generally improve the relative productivity of males more than of females. Although females may be absolutely more productive in plough-based agricultural than in hunting and gathering societies, their lower productivity relative to males reduces the relative value of female children when ploughs are adopted.

Sons are the key intergenerational link in patrilocal households, but not in matrilocal households or in modern, nuclear ones. In the patrilocal context, marriage assigns responsibility for the production of a son to a bride. When a son, usually the first born, marries, his bride moves to his natal residence. This post-marital residence rule, which is usually combined with patrilineal inheritance, makes the production of a son early in marriage relatively important to a woman.[1] The earlier in her own life a son is produced, the sooner is uncertainty regarding old age security resolved, and the sooner she acquires a daughter-in-law to aid in the running of the household. Women who bear sons sooner may experience monetary transfers from male offspring at a younger age.[2] Unlike in the nuclear context, the primary motivation for bearing children in the patrilocal context may be investment, not consumption. The older generation is then better off with more children because this ensures greater old-age transfers (e.g. Samuelson (1958), Nugent (1985)). Siow and Botticini (2003) explain the coincidence of dowry and patrilocality across diverse cultures as a means of providing early inheritance to daughters, so

[1]See, for example Goody (1976), who documents the importance of dowry and bride price in pre-modern societies. Hajnal (1982) compares household structures in Northern Europe and South Asian countries using historical census data and parish records.

[2]For example, Kochar (2000) finds that only about 8% of elderly household members in rural Pakistan received monetary transfers from non-resident children, while about 85% received transfers from resident sons. Pakistani elders benefit from increased household public goods provision when their sons work more. In contrast, in Russia, where households are primarily nuclear, Kuhn and Stillman (2004) document the redistribution of old-age pension income in Russia by pensioners to their non-resident adult children. Cheuk and Uhlenberg (2010) discuss both the time and monetary contributions of grandparents to children's upbringing in Russia and other countries with nuclear household norms.

mitigating incentive problems of sons in family businesses. Modernization is strongly associated with changes in norms regarding the direction of net intergenerational transfers within families (e.g. Caldwell (1976), Caldwell (1978), Lee (1980), Willis (1982)).

Biological evidence from human genome sequencing in South Asia suggests that early arrivals to South Asian countries were matrilocal, meaning men moved into brides' natal households, at least before the diffusion of domesticated animals and plough agriculture. Biologists and anthropologists have been able to proxy the degree of migration of males versus females historically using sex-specific chromosomes obtained from mouth swabs, and by examining the chemical composition of teeth. For women, mitochondrial DNA (mtDNA) is a sex-specific molecule, and the degree of mtDNA similarity within geographical areas is suggestive of the extent to which married women continued to reside in their natal context.[3] For men, the Y-chromosome is similarly sex-specific. Oota, Pakendorf, Weiss, von Haeseler, and Pookajorn (2005) present evidence from the Mlabr hunter and gatherer tribe in Northern Thailand which suggests that there was also some reversion from settled agriculture to hunting and foraging in the past 500 to 800 years. Large-sample analysis of mtDNA and Y-chromosome similarities in Vietnam has yet to take place (Stoneking and Delfin (2010)), but small-sample results for hill tribes in neighbouring Thailand suggest that there is less mtDNA diversity amongst matrilocal than amongst patrilocal tribes (Oota, Settheetham-Ishida, Tiwawech, Ishida, and Stoneking (2001)). Bentley, Pietrusewsky, Douglas, and Atkinson (2005) use stable isotopes in teeth of people buried in Thailand during the period of intensification of agriculture to qualify the extent to which men and women were nourished as children by food in their region of burial. They find that women's nutritional intake as children more closely matches that of food available locally than does that of men, and speculate that this reflects matrilocal household formation rules.

Clearly, both history and geography may be important to our understanding of prevailing social norms. Greif (1994), and Nunn (2012) explain contemporary cultural differences as historical, rather than geographical legacies. Nunn and Wantchekon (2011) show that the slave trading in the 18th and 19th centuries impacts contemporary trust and social interactions in African countries. In contrast, the importance of innate geographical differences to culture is emphasized by Durante (2010), amongst others. Spolaore and Wacziarg (2013) demonstrate the importance of ancestoral population traits to development outcomes, and discuss whether productivity is directly impacted by these traits or through diffusion rates of innovation.

Anthropologists have long posited that the origins of household formation rules relate to both technology and productivity. Aberle (1961), in a statistical analysis of Murdoch's *World Ethnographic Sample* (1957) concludes:

"The origins of matrilineal systems are probably to be sought in technology, division of labour,

[3] There are several reasons why mtDNA is the preferred molecule of study in human evolution research. This molecule reflects maternal inheritance, has a high mutation rate, and other attractive features. See, for example, Pakendorf and Stoneking (2005).

types of subsistence activities, and the ecological niches in which these activities occur."

Anthropologists also widely accept that norms regarding household formation are related to preferences for male children. The masculinization of under 5 sex ratios in India, South Korea and China since the advent of prenatal ultrasound has been consistently linked to dowry and to post-marital residence rules (Arnold and Zhaoxiang (1986), Das Gupta, Jiang, Bohua, Zhenming, Chung, and Hwa-Ok (2003), and Das Gupta (2009)). More recent masculinization of sex ratios in Albania, the Caucasus and the Former Yugoslavia is similarly attributed (Giulmoto (2009), and UNDP Albania (2012)). To date, however, the economics literature has not linked contemporary son preference to household formation and inheritance rules, and these informal rules to the suitability of land for the adoption of the plough. To do so requires data encompassing substantial geographical variation in household formation rules, as well as information on exogenous attributes of land and indicators of plough usage.

This paper examines the hypothesis that household formation and inheritance rules can explain the relative value placed on male versus female children, and that these rules are moderated by the geographical suitability for plough agriculture. Vietnam is an ideal country to study in this regard, since both strong matrilocal and patrilocal residence rules persist, and since ethnicity clearly identifies these rules. Patrilocal ethnicities are also patrilineal in Vietnam, and matrilocal are matrilineal, so post-marital residence rules are aligned with those of inheritance. The paper proceeds as follows: Section 2 presents a simple model describing differences in household production across agricultural and hunter-gatherer societies, based on the Boserup (1970) hypothesis. Section 3 presents summary statistics from the 2002 Demographic and Health Survey which suggest differential fertility and infant mortality patterns by household formation rule, and according to the sex of the first-born child. In Section 4, it is shown that exogenous geological features have strong causal effects on livestock density across districts, and on the 2009 under-5 sex ratio. Across patrilocal and matrilocal groups, and across geological areas, strong and robust differential impacts of male first-borns on fertility and under-5 mortality patterns are shown. Section 5 discusses these findings in the context of the 20th century record of movement between patrilocal peasant-based agricultural to modern, nuclear, households in the Former Soviet Union. Section 6 concludes.

2 Model

The insights of Boserup (1970) are first employed to suggest some simple relationships between land quality, technological choice, and the relative productivity of male and female inputs. Boserup hypothesized that women's status was relatively high in societies practising shifting cultivation agriculture and hunting and gathering, because livestock-drawn plough technology adopted during agricultural intensification was most employable by men. Livestock-drawn ploughing requires physical strength, and so men are more likely to draw ploughs. This both increases the potential relative productivity of men and requires relatively more male labor input than non-plough food production.

The relative productivity of males and females may be a major factor in determining household formation and inheritance rules, if relative productivity determines say in household decisionmaking. Alesina, Giuliano, and Nunn (2011) show that suitability of the soils in a country for plough agriculture is negatively related to current female labor force participation across countries, and amongst the second generation diaspora in the US. This suggests that the suitability of land for plough agriculture may be related to household formation rules, if women's decisionmaking power in the household is positively correlated with her potential productivity relative to men. If women are more able to enforce matrilocal residence where their productivity relative to men is high, matrilocality should be observed in areas less suitable for plough agriculture. If hunter-gatherer societies were matrilocal before the advent of farming, areas less geologically suited to the plough should be more likely to practise matrilocal household formation today.

I use a simple production function to help illustrate how household i makes choices amongst available technologies $A_{M,i} = A_M$ where $i = 1, \ldots.$. Here the subscript M refers to males, and F, to females. In the context of rice farming families in Vietnam, plausibly exogenous components of this technological choice are soil texture and land slope. Since the decollectivization of agriculture under *Doi Moi* in 1986, family farming has again dominated, and so households can potentially be considered economic units in contemporary data.

The technology employed by males, A_M, is M-augmenting, so that a given unit of male labor input makes a greater contribution to output the higher is A_M. Assume that men draw ploughs, prepare and seed land but that, in the absence of men, women might also engage in these activities. Here M denotes units of male labour, while F denotes units of female labour. These are not then necessarily actual numbers of males and females involved in production, but measures of the respective intensity of employment of male and female workers in agriculture, perhaps in hours per day or weeks per year.

The technological parameters are A_M, and A_F. Technology A_M can be thought of as representing ploughs and tractors, as well as the energy which powers them. It is assumed that $A_M \geq 1$ and A_F=1, consistent with the stylised fact that little technological innovation is possible in the agricultural activities dominated by women. The weeding and hoeing tasks in which women engage in paddy agriculture are relatively difficult to mechanize, because they require more precise actions than does ploughing. Although women may work very hard in these activities, and be absolutely more productive than in contexts without plough agriculture, their productivity relative to that of males is potentially lower. As well, allow male and female labor to have different importance to production: $\gamma = \gamma_F + \gamma_M = 1$.

The household agricultural production function can be described using constant elasticity of substitution (CES) technology, with male and female inputs. Let Y_i denote output from agriculture, and Q be a vector denoting the quality of the land, which might also encompass the reliability of weather associated with this land. Given technology and M and F, output is moderated by the potential productivity of the land. Let p_r denote the market price of agricultural output, and p_{A_M} the price of technology employed by M. Let σ denote the elasticity of substitution between M and F.

$$Y_i = Q * \left[\gamma_F \left(A_F * F\right)^{\frac{\sigma-1}{\sigma}} + \gamma_M \left(A_M * M\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{1-\sigma}}$$

The relative productivities of M and F are easily derived:

$$\frac{MP_M}{MP_F} = \frac{\gamma_M}{\gamma_F} \left(A_M\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{M}{F}\right)^{-\frac{1}{\sigma}}$$

Because Q affects output for given A_M, M and F, and because technology costs p_{A_M} per unit, the decision to adopt technology will be impacted by land quality. Output prices p_r will also impact the technology adoption decision, so the importance of land quality is also arbitrated by the relative prices of output versus the technological input.

Assume that the profits from agriculture for family i can be denoted as follows:

$$\begin{aligned} p_r Y_i - p_{A_M} * A_m &= p_r f(Q, A_M, M, F) - p_{A_M} * A_m \\ &= p_r * Q * \left[\gamma_F \left(A_F * F\right)^{\frac{\sigma-1}{\sigma}} + \gamma_M \left(A_M * M\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{1-\sigma}} - p_{A_M} * A_m \end{aligned}$$

The above expression for profits from family farming suggests that technology used by males will become more sophisticated as Q rises, because at low Q, output cannot be increased greatly by technological adoption. Let A_M^* denote the profit-maximizing level of technology employed by M to produce Y_i.

$$\frac{\delta A_M^*}{\delta Q} > 0$$

The case of $\sigma > 1$, where M and F are gross substitutes in production, is the most relevant to the Boserup hypothesis. It is commonly-observed in Vietnam that women do men's soil-preparation work if households are women-headed, or males have migrated to the city, but not otherwise.

What happens when technology employed by M improves, that is A_M^* increases, perhaps because p_{A_M} has fallen?

$$\frac{\partial \frac{MP_M}{MP_F}}{\partial A_M^*} > 0$$

Households choose technology A_M^* partly on the basis of Q, which may encompass all exogenous geological features impacting the potential of land for agricultural output. As the technology employed by M improves, there are more buffalo and cattle per unit of land, and the productivity of M relative to F rises.

As well, A_M^* can be biased towards M, whose relative use in production is increasing in A_M^*. The choice of A_M^* may be associated with changes in the relative value of M and F. As $\frac{M}{F}$ changes:

$$\frac{d\left(A_M^*\right)^{\left(\frac{\sigma-1}{\sigma}\right)}}{d\left(\frac{M}{F}\right)} \geq 0$$

If M and F are gross substitutes, the relative economic status of women may decrease as they become less used in production, since the relative productivity of men is simultaneously increasing. An increase in $\left(\frac{M}{F}\right)$ might change the profit-maximising technological choice, A_M^*, enough that:

$$\frac{d\left(\frac{MP_M}{MP_F}\right)}{d\left(\frac{M}{F}\right)} > 0.$$

For example, more use of tractors for ploughing may be observed concurrently with a declining relative productivity of women agriculture if the technology used in women-dominated tasks is unchanged while A_M^* improves.

The above formulation of the Boserup hypothesis has at least two testable implications:

1. Where Q is higher, the benefits to technology adoption are more likely to exceed costs, and so relatively great plough use should be observed. A testable implication of this is that more water buffalo and cattle per square kilometre (km^2) should be employed where land is more suitable for ploughing, since these are the two domesticated animals most used in ploughing in Vietnam.

2. Where Q is higher, $\frac{M}{F}$ should be greater, because of the greater net benefit to technology adoption. The relative productivity of males compared to females is greater, and so household formation and inheritance rules will tend to favour men. Since sex-selection technology and abortion are now widely available in Vietnam, there should be more missing girls where land quality is more suitable for plough agriculture. As well, the reactions of households to the sex of the first-born child should differ across high Q and low Q contexts.

3 Data and Summary Statistics

Vietnam is a post-communist country which began a process of gradual market reforms in 1986. In 2011, Vietnam had an under-5 ratio of boys to girls of 1.11, according to the CIA World Fact Book (2011). The DHS 2002 sample suggests that Vietnam is one of the world's least religious developing countries, with more than 77% of women reporting that they are atheist or have no religion. A further 14% are Buddhists, with the remainder Catholic, Protestant, Cao Dai, Hao Hao or other.

Vietnam encompasses significant geographical variation in household formation rules. In the Central Highlands, only 11% of married DHS respondents aged 15-30 have their father-in-law as household head, whereas 28% of such women reside with their parents. The residents of these Highlands, labelled 'Montagnards' by the colonial French, are traditionally matrilineal and matrilocal, and rely on hunting and gathering with shifting cultivation and slash-and-burn agriculture. Families generally reside in longhouses with 10 to 20 residents (Salemink (2003)). In this context, girls are the key intergenerational link, because grooms join the natal households of brides and inheritance is matrilineal.

Variation in the quality of land can be measured using the World Soil Database (United Nations Food and Agriculture Organisation (2013)), combined with rainfall information at the district level, and topographical information from ARCGIS. The relationship between exogenous components of land quality, Q, and technological choice, as proxied by the density of buffalo and cattle per square kilometre, can then be examined. Similarly, relationships between Q and child sex ratios can be investigated, using recent census data.

Although the 2009 IPUMS (Minnesota Population Center (2013)) census microdata contains little information about ethnicity, both the Vietnam 1999 IPUMS microcensus data and the DHS 2002 do. There is some ambiguity about the household formation rules of smaller ethnic groups, but for the larger ethnic groups, scholars broadly agree. Just over 8% of respondents belong to matrilocal ethnicities. Here patrilocal ethnicities are considered to be Vietnamese, Tay, Muong, Nung and Chinese, while matrilocal ethnicities are Thai, Khmer, Hre, Phu La, E de, Dao, Co tu, and Cham. These classifications are derived from Schneider (1961), Ireson-Doolittle and Ireson (1999), Kapur-Fic (1998), Salemink (2003), and from the *Ethnographic Atlas* (Murdock (1967)).[4] These matrilocal ethnicities generally speak Malayo-Polynesian languages, which are distinct from Vietnamese. It is thought that these ethnic groups were driven from coastal areas of Vietnam into mountainous regions in about the 9th century, by invading Vietnamese and Cambodian tribes.

[4] Classification of some groups, such as the Cham, is difficult, since household formation and inheritance rules appear to be evolving away from matriliny towards bilateral social organization. Similarly, although the Muong peoples are generally currently classified as patrilocal and patrilineal, they are thought to have been matrilocal and matrilineal until relatively recently. It turns out that results are not sensitive to the classification of the Muong, the Cham, or other small ethnic groups.

A comparison between the topological map of Vietnam and a map of the incidence of matrilocality within provinces suggests the relationship between suitability for plough agriculture and household formation rules. Figure 1 presents the province-level density of matrilocal ethnicities. This map is derived from the Vietnam 1999 IPUMS census microdata (Minnesota Population Center (2013)), which is the latest census data to contain detailed ethnicity information at the provincial level.[5] In Figure 2, the provincial mean land slope is plotted. The mean slope information is calculated at the provincial level using ARCGIS. The ethnicities referred to as 'Montagnards' by the French are relatively likely to be matrilocal and, consistent with their name, reside predominantly in provinces of Vietnam with the greatest mean slope of the land. Simple province-level regressions also show that, within regions of Vietnam, greater land slope is associated with significantly larger population fractions from matrilocal ethnicities, even after accounting for other land and climatic characteristics. These regression results are presented in Table 1.

Because there are sufficient respondents from both patrilocal and matrilocal ethnicities in Vietnam, it is possible to construct a natural experiment which gauges the relative importance of sons under these two household formation rules. The impact of the sex of the first-born child on subsequent fertility and under-5 mortality outcomes can be compared across women in matrilocal versus patrilocal ethnicities. This same quasi-experimental set-up can also be used to examine differences amongst residents of regions suitable for plough agriculture versus those less suitable ($LOWQ$) areas in these demographic outcomes, under the assumption that region of residence is unrelated to the sex of the first-born. The variable $LOWQ$ is proxied by residence in the Central Highlands and Northern Uplands regions of Vietnam. Unfortunately the DHS 2002 does not contain GIS codes, so that locational information is restricted to seven regions, comprising the North Uplands, Red River Delta, North Central, Central Coast, Central Highlands, South East, and Mekong River Delta. Amongst these regions distinguished in the DHS, the Central Highlands and the Northern Uplands have the greatest mean slope of land, and so the least conducive geological conditions for agriculture. About 23% of respondents reside in these two regions comprising $LOWQ$, although a majority of DHS respondents in even these regions are of patrilocal ethnicities. Around 19% of residents of $LOWQ$ regions are of matrilocal ethnicities, versus about 5% in other regions. Whereas within provinces of Vietnam the concentration of matrilocal ethnicities often exceeds 40% (see Figure 1), this is not true for any one region defined in the DHS.

In the 2002 DHS, the sex ratio amongst first-borns is statistically equal to the biological norm for both women residing in the patrilocal and matrilocal contexts. Amongst the 450 women in the matrilocal sample, the fraction of male first borns is 0.543 with standard error 0.0235, and amongst the 4940 in the patrilocal context it is 0.512 with standard error 0.007, using sample

[5]This data was originally produced by the General Statistical Office in Vietnam.

weights.[6] Moreover, for neither the patrilocal nor the matrilocal samples do characteristics of respondents vary according to the sex of the first-born child. In Table 2, it is shown that mean age at first marriage, mean age at first birth, the fraction of the sample with highschool and higher education, the fraction reporting a religion, and the fraction rural, do not differ by the sex of the first-born, either for patrilocal or for matrilocal groups. It is apparent that women from patrilocal ethnicities are somewhat older when they marry and have their first child, and that they are better-educated and less likely to live in rural areas. These findings, combined with the finding that patrilocal ethnicities reside in regions more conducive to plough agriculture, are consistent with Neolithic advantages having persistent impacts on current living standards (Olsson and Douglas A. Hibbs Jr. (2005), Ashraf and Galor (2011)). Plough-based societies are currently more prosperous than hunter-gatherer societies, and ploughable lands also potentially provide more economic locations for non-agricultural activities. However, these differences across patrilocal and matrilocal societies will not interfere with the identification strategy.

3.1 Fertility by sex of first-born

The differential impact on fertility of the sex of the first born by household formation rules is apparent from simple means. Table 3 shows that, in the matrilocal context, women have significantly more children if their first born child is male. In contrast, in the patrilocal context women have fewer children if their first born child is male. This is true both amongst all women aged 15-49 who have born children (columns (1) and (2)) and also amongst women aged 40-49 (columns (3) and (4)) who have nearly completed their childbearing.

Results are generally similar when distinguishing residents of $LOWQ$ and other regions. $LOWQ$ and non-$LOWQ$ regions also both have biologically normal ratios of male to female first-borns.[7] Although not statistically significant at the 10% level, in $LOWQ$ regions women with female first-borns have fewer mean numbers of children than those with male first-borns, as shown in Panel A of Table 4. Amongst residents of regions more suitable for plough agriculture, however, a male first-born is reduced with statistically significant reductions in fertility (Panel B). Given the fact that relatively few residents of even $LOWQ$ regions are of ethnicities now considered matrilocal, the strength of these results is perhaps surprising.

[6]The respective p-values of tests of the equality of these means to the biological norm of 105 boys per 100 girls are p=0.17, and p=0.99.

[7]In $LOWQ$ regions, the mean fraction of first-borns that are male is 0.510 with standard error 0.014, using sample weights. In non-LOWQ areas the mean is 0.517 with standard error 0.008.

3.2 Under-5 mortality by sex of first-born

Similarly, mortality of first-borns before age 5 appears to differ across patrilocal and matrilocal households by the sex of the first-born. In Table 5, it is apparent that mortality of male first-borns in the matrilocal context is far higher than that of female first-borns. In contrast, in the patrilocal context, the under-5 mortality rate of male first-borns does not differ from that of females. These mortality results are consistent when considering women aged 15-49, (columns (1) and (2)) or the subsample of women aged 40-49 (columns (3) and (4)). In populations without son preference male mortality rates are slightly higher, and this is generally attributable to greater susceptibility of male infants to illness. The 105 to 100 boy to girl ratio observed at birth in normal human populations is a result.

In both $LOWQ$ and other regions, under-5 mortality of male first-borns is higher than female. In Panel A of Table 6, it is shown that women aged 15-49 are more than twice as likely to have had a first-born die in $LOWQ$ areas if the child was male compared to female. In other regions (Panel B), mortality differences amongst male and female first-borns are statistically significant, but less pronounced. However, differences between mortality of male and female first-borns are not statistically different amongst the 40-49 year old sample, for either $LOWQ$ or other regions.

4 Estimation

The Boserup (1970) hypothesis suggests that, where land characteristics are less conducive to the adoption of plough technology, A_M, different household production functions should be used. In this way, land characteristics moderate the relative value of male versus female work. Although females may be as productive in absolute terms across different geological zones, it is their relative productivity in the household which likely determines the relative value of male versus female children. For this reason, the commonly-observed intensive labor of women in rice paddy weeding in Vietnam does not necessarily suggest that the patrilocal context of paddy agriculture is incompatible with son preference. Without measures of the relative productivities of males and females across different geographical areas, it is not possible to directly examine how women's relative contribution to household production varies across the matrilocal versus patrilocal context. In the absence of productivity information, the relative contribution of women to output may be proxied using relative employment rates of men and women in specific agricultural activities, as in Carranza (2011). Still, these measure only the extensive margin (relative participation), and at the time of year in which the census took place. For this reason, the relative employment rates of men and women in farming and non-farming activities are not here examined.

Two outcomes are examined: (1.) Density of cattle, which is assumed to capture the relative technological and plough intensivity in agriculture in a district, in 2005. This is a potential proxy for $\frac{\delta A_M^*}{\delta Q}$, if plough and cattle numbers are positively correlated. (2.) The 2009 under-5 boy/girl sex ratio. This ratio is assumed to capture differences across regions in the relative value of girls. Livestock data is from the 2005 Global Cattle district-specific density count for Vietnam (FAOSTAT (2005)).

Soil data comes from the World Soil Database, and includes information on acidity and alkalinity, drainage, and soil texture. This information has been merged with rainfall and temperature information, information on the mean slope of land in a district, soil alkalinity and acidity information, and 2005 information from the Food and Agriculture Organization (FAO) on livestock counts by district. Because both buffalo and cattle are primarily used for ploughing land and other soil preparation activities primarily done by men, these livestock numbers are used as an indicator of A_M, the farm production technology employed by the household.

Soil nutrient content can be altered by fertilizer use, but soil texture and land formations are largely exogenous. Exogenous soil characteristics, soil texture and mean slope of land, are employed to predict the density of livestock (buffalo plus cattle) per km^2 in a district, and the under-5 sex ratio in the 2009 IPUMS microdata sample from the Vietnamese Census. Soil texture is measured by the respective percentages of clay, silt, gravel and sand in the topsoil, with percentage silt as the reference group. Topsoil is considered to be the first 30 centimetres of soil, which is most relevant because deep soil tillage seldom exceeds 25 centimetres. Clayey soil with little drainage is optimal for the cultivation of paddy rice. This 'wet rice' grows well in muddy pools, and ploughing of wet clayey soil with water buffalo or cattle is relatively easy. Variation in rainfall is also less detrimental to crop output when rice is grown in paddies, because pooled paddy waters insulate crops agains rainfall fluctuations. In contrast, silty, sandy, and gravely soils are less conducive to rice paddy cultivation. Although wet rice can readily be cultivated in terraced paddies on hillsides, more extreme ruggedness of terrain makes terraced cultivation infeasible.

The suitability of land for farming appears to be strongly related to land slope, which is consistent with the stylized fact that Vietnam's Montagnards practise hunting and gathering and slash-and-burn agriculture with shifting cultivation. Panel A of Table 7 shows that, conditional on exogenous soil texture characteristics, the mean slope (measured as rise over run) is importantly correlated with numbers of livestock per capita. This slope of the land varies from 1 to 7 in these data, with a mean across districts of 3.3. The preferred specification (column (4)) includes controls for mean annual temperature and rainfall in the district, and 4 dummies for soil pH levels. As the mean slope of the land rises by 1, the number of cattle per kilometre squared decreases by 10. Mean land slope, but not soil texture, turns out to be key to explaining livestock levels.

The 2009 microcensus sample includes 685 districts. Of these the administrative GIS spatial data layer for Vietnam comprises 674 districts. All GIS data were sorted based on this administrative spatial data layer, so 11 (=685-674) district means had to be dropped. Another 3 observations were dropped because 3 of the remaining 674 districts did not have corresponding microcensus values.[8] The Harmonized World Soil Database did not have soil observations for Kien Luong, so this district had to be dropped from the dataset. An additional 3 island districts also had to be dropped, due to insufficient data from the Global Buffalo and Cattle Density datasets of FAO. It is important to note that several districts did not have a corresponding buffalo and cattle data points because of where district borders and GIS livestock data fell. Districts without a corresponding value were manually inspected and given a value in the instance of this GIS discrepancy. However, it was thought that using this process for an island could compromise data quality. A similar process was used to sort the Terrain Slope Classes of the World data, resulting in an additional 2 island districts being dropped. Of the original 685 observations, 20 observations were dropped, resulting in 665 observations.

The 2009 IPUMS microcensus data show that greater land slopes in a district are also strongly associated with more girls relative to boys under 5. As the mean slope in a district (rise over run) rises by 1, the fraction of boys per girl diminishes by 0.018, significant at the 1% level. As with the results for livestock, mean land slope, but not soil texture, turns out to be very important to explaining the dearth of girls. This result is robustly statistically significant, after conditioning on mean annual temperature and rainfall, and soil pH dummies. Together the results of Panels A and B support a hypothesis that the relative value of female children is higher where agricultural technology favours the relative productivity of females. Groups residing in areas unsuitable for plough agriculture developed female-centric household formation and inheritance rules because the high relative productivity of females permitted women a relatively great say in decisionmaking. For Vietnam, this suitability appears more related to land slope than to soil texture. For neither outcome are the soil texture variables jointly significantly different from zero.

If the relative values of boy and girl children vary by the suitability of the land for the adoption of plough agriculture, fertility and infant mortality should both be impacted by geology. A valid natural experiment compares the causal impact of the sex of the first born on fertility and under-5 mortality, across matrilocal and patrilocal ethnicities. Differences in the causal impacts of a male first-born on, respectively, fertility and under-5 mortality are next estimated by OLS

[8] When districts did not have an exact match among the two datasets, district names were adjusted manually for spelling variations (i.e. Dak Lak and Dac Lac) and character transferability (B?c Liu became Bac Lieu). Due to the multitude and similarity of Vietnamese district names, districts with characters outside of the English alphabet system were translated cautiously. Districts were cross-referenced to a list of districts in the same region and province and discretion was used. At the end of this process, 3 districts did not have a match. This was likely because 1 was an island, 1 was a township and the match of the remaining district was indistinguishable (Tam ??o). The last discrepancy might be explained by changing district-level borders. All possible matches were explored, but the remaining unmatched census districts were not in the same province as any of the 3 observations.

using the following equations:

$$\begin{aligned} OUTCOME_{ij} &= \beta_0 + \beta_1 FBBOY + \beta_2 FBBOY * MATRI + \\ &\quad \beta_3 MATRI + \beta_4 AGE + \gamma * CONTROLS + \mu_j + \epsilon_{ij} \end{aligned}$$

, and:

$$\begin{aligned} OUTCOME_{ij} &= \beta_0 + \beta_1 FBBOY + \beta_2 FBBOY * LOWQ + \\ &\quad \beta_3 LOWQ + \beta_4 AGE + \gamma * CONTROLS + \epsilon_{ij} \end{aligned}$$

Here i refers to individual i in region j, and the two outcomes to be considered are total children born, and mortality amongst first-borns before age 5. Controls include a linear term in age, regional dummies, and dummies for highest educational attainment. As well, specifications are estimated including as controls age times ethnicity interaction terms, religion and religion times ethnicity interaction terms, regional fixed effects, and regional times rural interaction terms.

Controls in the second specification include a linear term in age and dummies for highest educational attainment. As well, specifications are estimated including religious dummies, matrilocality, matrilocality times religion interactions, and matrilocality times male first-born interactions. This last control is entered to examine whether or not the differential effects of male first-borns across $LOWQ$ and more plough-appropriate regions can also be picked up by the matrilocality times male first-born effect. If so, the coefficient β_2 should become statistically insignificant when this variable is included. Regional fixed effects cannot be included.

4.1 Fertility

The impact of household formation rules on fertility is robust in multivariate analysis which accounts for religion and regional factors. The main coefficients of interest are β_1 and β_2. These reflect, respectively, the main causal effect of a male first-born on fertility, and the differential impact of this effect on women in the matrilocal versus patrilocal context. In Panel A of Table 8, it is shown that women in the matrilocal context have significantly more children when their first-born child is male, *ceteris paribus*. In contrast, women in the patrilocal context have significantly less. The sum of the coefficients β_1 and β_2 is not statistically different from zero.[9] Similar results prevail when comparing fertility outcomes amongst women aged 40-49, as in Panel B.[10]

[9] The F-test that the sum of these coefficients equals zero accepts at the 10% level, with p-value= 0.266, in the preferred specification of Column (6).

[10] The F-test that the sum of these coefficients equals zero accepts at the 10% level, with p-value=0.245.

Estimation examining the interaction between the sex of the first born and land quality concurs. In Panel A of Table 9 it is first shown that a male first-born increases fertility significantly more in $LOWQ$ areas than in others, and that this result is robust to extensive individual controls (columns (1) through (4)). Further support for the hypothesis that land quality determines the household formation rule by an ethnicity is provided in column (5). In this specification, the interaction term between matrilocal ethnicity and a male first-born, $FBBOY * MATRI$, is also included as a control. When this is done, the statistical significance of the variable of interest, $FBBOY * LOWQ$, disappears. This is equally true in Panel B, which restricts the sample to women aged 40-49.

4.2 Under-5 mortality

Multivariate analysis also shows that mortality amongst first-borns under-5 is relatively high for males in the matrilocal context. Panel A of Table 10 illustrates, for women aged 15-49. It is apparent that, *ceteris paribus*, male mortality is not different from female in the patrilocal context. First-born males in the matrilocal context are about 8% more likely to die before age 5 than are either first-born females in the matrilocal context, or first-borns of either sex in the patrilocal context. Unlike for the fertility results, a test of the equality of the sum of coefficients β_1 and β_2 to zero here rejects at the 1% level. Male first-borns are more likely to die in all contexts, but particularly so amongst matrilocal ethnicities. Amongst women aged 40-49, male mortality in the matrilocal context is also relatively high, both compared to female first-borns in the matrilocal context and to either males or females in the patrilocal context (Panel B). A test of the equality of the sum of coefficients β_1 and β_2 to zero here rejects at the 5% level. The mortality results support an interpretation that first-born boys are of relatively low value in the matrilocal context, since they will not reside with their mothers in old age or inherit from their natal family.

Consistent with the model, under-5 mortality of first-born boys is also about 3% higher in $LOWQ$ regions, compared to other regions, *ceteris paribus*. In Panel A of Table 11, it is shown that this result holds with the addition of extensive controls (columns (1) through (4)). As with the fertility outcomes, however, the inclusion of the interaction term $FBBOY * MATRI$ makes the statistical significance of the $FBBOY * LOWQ$ interaction disappear. Amongst women aged 40-49, however, results for under-5 mortality are less salient than for fertility. Panel B shows that, although coefficients of the $FBBOY * LOWQ$ variable are of similar sign and magnitude as for the full sample, they are no longer statistically significant in any specification. Still, the addition of the $FBBOY * MATRI$ control (column (5) of Panel B) results in a reduction in the estimated coefficient of interest, as in the full sample and in the fertility results.

5 Discussion

Data from other countries participating in the DHS also suggest that household formation rules are importantly correlated with the demand for sons.

Social norms regarding post-marital residence can be roughly summarized by examining household headship amongst married women aged 15-30, as in Grogan (2012).[11] The patrilocality index refers to the fraction of these women who reside with their father-in-law. The DHS surveys generally define a household as a person or group of related or unrelated persons who live together in the same dwelling unit or in connected premises, who acknowledge one adult member as the head of the household, and who have common arrangements for cooking and eating meals.[12] In column (1) of Table 12 DHS countries are ranked by this patrilocality index. Armenia, a Former Soviet Union country where Orthodox Christianity is the religion of 98% of DHS respondents, ranks highest of all countries. Two-thirds of married women under 30 reside in households where their father-in-law is the head. At the bottom of the patrilocality index is São Tomé and Príncipe, where essentially no married women under 30 reside with their fathers-in-law. Although this characterisation of household formation rules does not take into account differentials in fertility across countries, it nevertheless provides a rough description of post-marital residence rules.

The DHS data also make it clear that co-residence of married women in their natal household is relatively rare. In column (2) of Table 12 the mean fraction of women under 30 residing with parents is given. The highest level of such matrilocal residence is observed in Maldives, at 37%. In Ukraine, and also Moldova, the incidence of matrilocality is greater than that of patrilocality. Both patrilocality and matrilocality may partially reflect housing shortages, which were severe during the Soviet period. Across the samples, however, matrilocality is relatively rare. This is particularly so in the most patrilocal contexts.

It is possible that the lack of formal ownership rights in communist countries reinforced patrilocal household norms by increasing the importance of physical presence to maintaining user rights, as is the case today in China. Post-communist countries generally rank high on the patrilocality index. This is important because these countries also had relatively high compulsory schooling requirements under communism (typically 10 or 11 years), and because women's labor force participation was encouraged by the state. However, in the most patrilocal post-communist countries, and with the exception of Vietnam, female labor force participation rates are now very low. The simple correlation between the patrilocality index (column (1)) and the employment rates of women 15-49 (column (3)) is -0.47, and is -0.57 amongst the 8 post-communist countries of the sample.

[11] Age 30 is taken as the age cut-off to avoid confounding post-marital residence rules with mortality amongst male household heads.

[12] The Demographic and Health Surveys (1994) provides an in-depth discussion of issues in defining household composition, which have guided interviewer training in subsequent DHS surveys.

Even without accounting for sampling variation, it is apparent that more patrilocal countries are those where the sex of the first born has the greatest impact on fertility. Figure 3 plots a graph relating the patrilocality index to differences in completed childbearing amongst women whose first-borns were female versus male. For women aged 40-49, country-level differences in numbers of children born to women with female versus male first-borns are plotted on the Y axis, and the patrilocality index on the X axis. The slope of the line fitted with ordinary least squares is 0.374, and is highly statistically significant (P-value= 0.003 with robust standard errors). In contrast, there is no strong relationship between the matrilocality index and this difference: A similar regression yields a coefficient on the matrilocality index of 0.10 with a P-value of 0.867.[13] This is perhaps because, outside of Vietnam, only very small fractions of a country's population are matrilocal.

Differences in fertility by the sex of the first born are also strongly associated with female employment rate differences across countries. A simple regression explaining these differences as a function of female employment rates yields a coefficient of -0.183 with a P-value of 0.048. Figure 4 plots this relationship.

The contrasting evolution of patrilocality in Russia and peripheral Soviet economies in the 20th century supports a hypothesis that changes in female labor demand led the trend away from patrilocal marriage contracts, and towards city-dwelling nuclear households. The strong and robust negative association between the patrilocality index and current employment propensities suggests that patrilocality may decline as labor market opportunities for women improve. Russia in 1917 was largely a peasant society, composed of thousands of small rural villages where arranged marriages and large households were the norm. In this sense it did not differ greatly from Russian Central Asia, or the Caucasus where household sizes were also large and marriage was arranged by elders.[14]

In the rural and agricultural peripheral Soviet countries, including Armenia and Azerbaijan, the credible guarantee of age-defined state pensions does not appear to have been sufficient to change prevailing marriage contracts for women. Without non-agricultural employment opportunities, neither education nor pensions resulted in a move away from traditional household formation rules. A lack of property rights, and a ban on payments of dowry and brideprice did not successfully promote nuclear households. In Central Asian countries, including Kazakhstan, Kyrgyzstan and Tajikistan, bride price, known as *kalyn*, had been paid prior to Soviet rule. Poliakov (1992) reports that illegal bride price payments grew by 300 percent in Tajikistan

[13]These country-level means are available at `http://www.economics.uoguelph.ca/lgrogan/fig1totkidmeansbysexfirstborn.zip`.

[14]Russian peasants did not generally contract love matches even by 1917, as documented by Figes (2003). Under serfdom, landowners had determined who would marry whom. After the emancipation of the serfs in 1861, marriages were arranged by fathers of the bride or by villages collectively, and women continued to marry in their teens. After 1861, communities allocated land amongst peasants on the basis of household size. Households were generally patrilocal, and fertility rates were very high (Avdeev (2004)).

in the 1980s, a strongly patrilocal country. Families of wives might contribute livestock, but this wealth would formally remain the property of future children and not of the family of the husband (An-Naím (2001)). In post-Soviet Armenia, there is little evidence that either bride price or dowry payments have again become important. While dowry may have helped parents resolve incentive problems of their working-age sons in patrilocal households in some historical contexts (Siow and Botticini (2003)), patrilocality and dowry appear to be little related amongst the post-Soviet countries.

In the peripheral Soviet republics of the Caucasus and Central Asia, industrialization did not occur and, despite the Soviet objective of bringing women into the workforce, rural opportunities for paid employment remained limited. Fertility dropped very strongly in Russia from the beginning to the end of Soviet rule, but declines were smaller in the southern Soviet republics. In these republics, little industrialization had taken place despite huge improvements in women's education. Although Soviet policies forbade polygamy, child marriage, the veil, sent girls to school, and tried to promote nuclear household norms, women remained largely outside productive employment. This was especially true in rural areas, where the majority resided even at the end of the Soviet era.

In Soviet Russia, factory production resulted in stable off-farm employment which was not subject to weather shocks, for both men and women. The ability to co-insure in the face of adverse weather or health shocks may also help explain why households were historically larger in agricultural areas. Large households may afford economies of scale when a majority of food is home produced, and there are few labour-saving appliances. In Russia, industrialization may have undermined rationales of mutual insurance, economies of scale, and old-age security for larger households. In the new cities, food was bought at centrally-set prices, and often prepared communally at subsidized workplace or school cafeterias. Soviet-era industrialization may have been a key factor in the evolution of women's status in Russia. Similarly, South Korea's rapid industrialization eventually reduced preferences for boy children, despite social policies which discouraged female labor force participation (Chung and Das Gupta (2007)). Industrialization in Vietnam might thus be expected to reduce differences in the relative importance of sons and daughters across ethnicities, as land quality becomes less important in determining household formation and inheritance rules.

6 Conclusions

The potential impacts of geology and technology on social norms regarding household formation and inheritance have not been widely understood by economists. This paper employs the 2002 Demographic and Health Survey data from Vietnam, the 2009 microdata census, and district-level livestock and geological information to demonstrate the importance of exogenous land characteristics and household formation rules to the demand for sons. A simple model is developed in which men and women are gross substitutes in agricultural production, men are primary users of plough technology, and land is of heterogenous quality. The relative value of children of a given sex is then partly determined by the suitability of land for plough agriculture. It is shown that matrilocal ethnic groups in Vietnam, who generally reside in more mountainous areas, have very different fertility behaviour from the patrilocal groups in regions suitable for plough agriculture. Consistent with the hypothesis that patrilocal ethnicities place relatively high value on sons, women are found to have relatively few children if their first-born is male. In contrast, in the matrilocal context, both fertility and under-5 mortality are lower when the first-born is female.

Very little of the large program evaluation literature has explicitly considered social norms as important determinants of economic decisions. The finding that a first born male reduces fertility in more patrilocal contexts, but raises fertility in more matrilocal, suggests that the demographic impact of family planning might vary widely by this social norm. It also suggests that women's increased control over fertility may reinforce the low status of women in the patrilocal context: Access to contraception or SIT may widen the gap between boys and girls in mean numbers of siblings, particularly if there are no changes in household formation rules. The reduction in relative resources available to girls might, *ceteris paribus*, lead to reduced options for girls outside of marriage. Similarly, in the matrilocal context, the high under-5 mortality amongst male first-borns and the fact that these boys have more siblings, reinforces the relatively low status of males. Variation in norms regarding intrahousehold resource allocation may circumscribe the transferability of policy interventions across different contexts.

The present findings suggest that one potential correlate of patrilocal household formation rules is a lack of productive labor market opportunities for women. Women engaged in paddy agriculture may still be more productive than women in engaged in gathering activities in the Central Highlands and Northern Uplands, but it is their productivity relative to men which determines household formation and inheritance rules, and so the relative worth of boy and girl children. The dearth of girls under 5 in Vietnam and other countries may be partially a consequence of geological conditions which historically favoured the adoption of technologies improving the relative productivity of male labour. Off-farm work opportunities may be particularly important in such contexts to improving the relative value of female labor and female children.

Table 1: The geographical correlates of household formation and inheritance rules, Vietnam

Dep. var. is fraction of individuals in province of matrilocal ethnicity			
% clay in soil	-0.0057	-0.0031	-0.0034
	(0.007)	(0.004)	(0.005)
% sand in soil	-0.0087	-0.0063*	-0.0069*
	(0.006)	(0.004)	(0.004)
% gravel in soil	-0.0176*	-0.0035	-0.0006
	(0.010)	(0.010)	(0.010)
mean slope of land in province	0.0836***	0.0812***	0.0944***
	(0.022)	(0.017)	(0.020)
mean temperature in province			0.0024*
			(0.001)
mean annual rainfall in province, cm			0.0310
			(0.102)
constant	0.3857	0.0989	-0.5606
	(0.416)	(0.283)	(0.475)
adj.-R^2	0.26	0.64	0.63
No. obs.	61	61	61

1999 IPUMS microcensus data from Vietnam. All estimates control for region of Vietnam (North East, North West, Red River Delta, North Central, Central Coast, Central Highlands, South East, Mekong River Delta). Weights are provincial population means. *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors are robust.

Table 2: Descriptive statistics by household formation rule and sex of first-born, Vietnam 2002 DHS

	age first marriage		**age first birth**		**yrs. school**		**no religion**		**rural resident**	
sex of first-born:	male	female	male	female	male	female	male	female	male	female
PANEL A: Matrilocal ethnicities										
mean	18.6250	18.2913	20.5947	20.5282	4.4192	4.5534	0.7568	0.7940	0.9620	0.9565
	(0.210)	(0.224)	(0.211)	(0.220)	(0.216)	(0.224)	(0.027)	(0.029)	(0.012)	(0.015)
P-value t-test equality	0.353		0.851		0.712		0.415		0.779	
PANEL B: Patrilocal ethnicities										
mean	20.7378	20.6876	22.7013	22.6562	7.9537	8.0496	0.7866	0.8029	0.7879	0.8007
	(0.069)	(0.069)	(0.071)	(0.071)	(0.065)	(0.065)	(0.008)	(0.008)	(0.008)	(0.008)
P-value t-test equality	0.638		0.684		0.346		0.174		0.307	

DHS 2002 data from Vietnam. Sample weights employed. Standard errors are robust. Women aged 15-49 with at least one child are included.

Table 3: Fertility by household formation rule and sex of first-born, Vietnam 2002 DHS

	All		**Women aged 40-49**	
	Male first-born	Female first-born	Male first-born	Female first-born
PANEL A: Matrilocal Ethnicities				
no.children	3.6199	3.1281	5.9655	5.1501
	(0.147)	(0.125)	(0.312)	(0.269)
P-value t-test equality	0.027		0.081	
PANEL B: Patrilocal Ethnicities				
no.children	2.5162	2.6662	3.4111	3.7000
	(0.028)	(0.030)	(0.059)	(0.060)
P-value t-test equality	0.001		0.003	

DHS 2002 data from Vietnam. Sample weights employed. Standard errors are robust.

Table 4: Fertility by region and sex of first-born, Vietnam 2002 DHS

	All		Women aged 40-49	
	Male first-born	Female first-born	Male first-born	Female first-born
PANEL A: LOWQ (Central Highland and Northern Uplands Regions)				
no.children	3.0318	2.9039	4.4197	4.1247
	(0.074)	(0.062)	(0.177)	(0.120)
P-value t-test equality	0.313		0.278	
PANEL B: Non-LOWQ				
no.children	2.5153	2.6510	3.4374	3.6935
	(0.031)	(0.033)	(0.066)	(0.068)
P-value t-test equality	0.005		0.012	

DHS 2002 data from Vietnam. Sample weights employed. Standard errors are robust.

Table 5: Under-5 mortality of first-born by household formation rule and sex, Vietnam 2002 DHS

	All		Women aged 40-49	
	Male first-born	Female first-born	Male first-born	Female first-born
PANEL A: Matrilocal Ethnicities				
no.children	0.1304	0.0327	0.1995	0.0406
	(0.021)	(0.013)	(0.050)	(0.033)
P-value t-test equality	0.001		0.019	
PANEL B: Patrilocal Ethnicities				
no.children	0.0481	0.0361	0.0452	0.0604
	(0.004)	(0.004)	(0.007)	(0.009)
P-value t-test equality	0.059		0.241	

DHS 2002 data from Vietnam. Sample weights employed. Standard errors are robust.

Table 6: Under-5 mortality of first-born by region and sex, Vietnam 2002 DHS

	All		Women aged 40-49	
	Male first-born	Female first-born	Male first-born	Female first-born
PANEL A: LOWQ (Central Highlands and Northern Uplands Regions)				
no.children	0.0822	0.0362	0.0877	0.0647
	(0.011)	(0.008)	(0.022)	(0.019)
P-value t-test equality	0.009		0.539	
PANEL B: Non-LOWQ				
no.children	0.0493	0.0356	0.0518	0.0579
	(0.005)	(0.004)	(0.009)	(0.009)
P-value t-test equality	0.040		0.663	

DHS 2002 data from Vietnam. Sample weights employed. Standard errors are robust.

Table 7: Exogenous land characteristics, technology and under-5 sex ratios in Vietnam

PANEL A: Dep. variable is buffalo and cattle/km^2 in district, 2002				
% clay in soil	0.4860*	0.0947	0.0868	0.1253
	(0.292)	(0.317)	(0.319)	(0.308)
% sand in soil	0.7996***	0.0362	0.0674	0.1308
	(0.276)	(0.300)	(0.289)	(0.283)
% gravel in soil	1.1477*	-0.1482	-0.0899	-0.0588
	(0.636)	(0.519)	(0.515)	(0.534)
mean slope of land in district	-4.1175***	-10.0877**	-9.4479**	-9.9347**
	(1.548)	(4.262)	(3.894)	(4.197)
mean temperature in district			0.0868	0.0777
			(0.144)	(0.143)
mean annual rainfall in district, cm			91.0741	87.7745
			(69.672)	(68.566)
constant	-14.9600	13.8013	-157.5683	-153.4633
	(19.017)	(22.625)	(120.915)	(120.422)
adj.-R^2	0.03	0.24	0.25	0.25
No. obs.	665	665	665	665
Controls:				
province	no	yes	yes	yes
temperature, rainfall	no	no	yes	yes
soil pH dummies	no	no	no	yes
PANEL B: Dep. variable is under-5 boy/girl ratio in 2009				
% clay in soil	-0.0001	-0.0000	-0.0000	0.0001
	(0.000)	(0.000)	(0.000)	(0.000)
% sand in soil	0.0000	-0.0000	-0.0000	0.0000
	(0.000)	(0.000)	(0.000)	(0.000)
% gravel in soil	-0.0004*	-0.0003	-0.0003	-0.0004
	(0.000)	(0.000)	(0.000)	(0.000)
mean slope of land in district	-0.0017***	-0.0018***	-0.0017***	-0.0018***
	(0.000)	(0.001)	(0.001)	(0.001)
mean temperature in district			0.0001	0.0000
			(0.000)	(0.000)
mean annual rainfall in district, cm			-0.0163	-0.0160
			(0.011)	(0.012)
constant	0.5370***	0.5213***	0.5329***	0.5295***
	(0.010)	(0.012)	(0.033)	(0.033)
adj.-R^2	0.04	0.20	0.20	0.20
No. obs.	665	665	665	665
Controls:				
province	no	yes	yes	yes
temperature, rainfall	no	no	yes	yes
soil pH dummies	no	no	no	yes

DHS 2000 data from Vietnam. All estimates control for region of Vietnam (North Uplands, Red River Delta, North Central, Central Coast, Central Highlands, South East, Mekong River Delta). Sample includes women with children. Sample weights employed. *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors are robust.

Table 8: Household formation rules and the impact of male first-borns on fertility in Vietnam

PANEL A: Dep. var. is total children born to women aged 15-49						
first-born male	-0.1673***	-0.1585***	-0.1590***	-0.1578***	-0.1573***	-0.1568***
	(0.035)	(0.035)	(0.035)	(0.035)	(0.034)	(0.034)
matri.*first born male	0.4367***	0.4140**	0.4471***	0.3171**	0.3074**	0.3175**
	(0.163)	(0.162)	(0.160)	(0.149)	(0.148)	(0.149)
matrilocal/matrilineal ethnicity	0.4131***	0.3909***	0.3325***	-1.9665***	-1.9898***	0.0000
	(0.104)	(0.103)	(0.103)	(0.359)	(0.359)	(0.000)
age	0.1160***	0.1176***	0.1176***	0.1098***	0.1099***	0.1099***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
completed higher ed.	-1.2922***	-0.9553***	-0.9251***	-0.9286***	-0.9028***	-0.8880***
	(0.067)	(0.074)	(0.074)	(0.071)	(0.072)	(0.072)
completed high school	-0.5721***	-0.4904***	-0.4795***	-0.4810***	-0.4636***	-0.4492***
	(0.041)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
adj.-R^2	0.42	0.44	0.45	0.46	0.46	0.46
No. obs.	5390	5390	5388	5388	5388	5388
Controls:						
rural	no	yes	yes	yes	yes	yes
religion	no	no	yes	yes	yes	yes
ethnicity*age interaction	no	no	no	yes	yes	yes
rural*region interaction	no	no	no	no	yes	yes
religion*ethnicity interaction	no	no	no	no	no	yes
PANEL B: Dep. var. is total children born to women aged 40-49						
first-born male	-0.2954***	-0.2734***	-0.2775***	-0.2757***	-0.2720***	-0.2717***
	(0.077)	(0.076)	(0.075)	(0.075)	(0.075)	(0.075)
matri.*first born male	0.9535**	0.9193**	0.9471**	0.6637*	0.6655*	0.7265*
	(0.411)	(0.409)	(0.399)	(0.398)	(0.400)	(0.398)
matrilocal/matrilineal ethnicity	0.7081***	0.6670**	0.5335**	-8.3331**	-8.4888**	-9.4977***
	(0.271)	(0.271)	(0.267)	(3.507)	(3.511)	(3.385)
age	0.1202***	0.1242***	0.1237***	0.1068***	0.1067***	0.1087***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
completed higher ed.	-1.8456***	-1.4345***	-1.4194***	-1.4412***	-1.4384***	-1.4045***
	(0.113)	(0.126)	(0.125)	(0.125)	(0.124)	(0.124)
completed high school	-0.8899***	-0.7690***	-0.7646***	-0.7837***	-0.7734***	-0.7396***
	(0.091)	(0.091)	(0.091)	(0.092)	(0.092)	(0.092)
adj.-R^2	0.29	0.31	0.32	0.33	0.33	0.34
No. obs.	1850	1850	1850	1850	1850	1850
rural	no	yes	yes	yes	yes	yes
religion	no	no	yes	yes	yes	yes
ethnicity*age interaction	no	no	no	yes	yes	yes
rural*region interaction	no	no	no	no	yes	yes
religion*ethnicity interaction	no	no	no	no	no	yes

DHS V data from Vietnam. All estimates control for region of Vietnam (North Uplands, Red River Delta, North Central, Central Coast, Central Highlands, South East, Mekong River Delta). Sample includes women with children. Sample weights employed. *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors are robust.

Table 9: Geology and the impact of male first-borns on fertility in Vietnam

	(1)	(2)	(3)	(4)	(5)
PANEL A: Dep var. is total number of children born to women aged 15-49					
first-born male	-0.1708***	-0.1647***	-0.1686***	-0.1648***	-0.1848***
	(0.039)	(0.038)	(0.038)	(0.038)	(0.039)
first-born male*LOWQ	0.2150**	0.2078**	0.1954**	0.1866*	0.0850
	(0.102)	(0.102)	(0.100)	(0.099)	(0.098)
LOWQ	0.3031***	0.3060***	0.1752***	0.1596**	0.2129***
	(0.064)	(0.065)	(0.067)	(0.068)	(0.069)
age	0.1136***	0.1139***	0.1154***	0.1157***	0.1155***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
completed higher ed.	-1.3984***	-1.3805***	-1.2880***	-1.2838***	-1.2836***
	(0.065)	(0.065)	(0.065)	(0.066)	(0.066)
completed high school	-0.6774***	-0.6692***	-0.5781***	-0.5716***	-0.5716***
	(0.038)	(0.039)	(0.039)	(0.040)	(0.039)
matri.*first born male					0.4420***
					(0.165)
adj.-R^2	0.38	0.39	0.41	0.41	0.41
No. obs.	5390	5388	5388	5388	5388
Controls:					
religion	no	yes	yes	yes	yes
matrilocal	no	no	yes	yes	yes
matri*religion	no	no	no	yes	yes
PANEL B: Dep. var is total number of children born to women aged 40-49					
first-born male	-0.3031***	-0.3061***	-0.3304***	-0.3296***	-0.3678***
	(0.086)	(0.083)	(0.083)	(0.083)	(0.084)
first-born male*LOWQ	0.4609*	0.4584*	0.4499*	0.4854**	0.3072
	(0.236)	(0.237)	(0.232)	(0.232)	(0.225)
LOWQ	0.4001***	0.4191***	0.2082	0.1633	0.2715*
	(0.141)	(0.143)	(0.154)	(0.158)	(0.155)
age	0.1126***	0.1129***	0.1200***	0.1234***	0.1205***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
completed higher ed.	-2.1407***	-2.0960***	-1.9443***	-1.9264***	-1.9300***
	(0.114)	(0.114)	(0.116)	(0.116)	(0.115)
completed high school	-1.2013***	-1.1661***	-1.0135***	-0.9905***	-0.9960***
	(0.083)	(0.086)	(0.089)	(0.089)	(0.089)
matri.*first born male					1.0386***
					(0.396)
adj.-R^2	0.21	0.23	0.26	0.26	0.27
No. obs.	1850	1850	1850	1850	1850
Controls:					
religion	no	yes	yes	yes	yes
matrilocal	no	no	yes	yes	yes
matri*religion	no	no	no	yes	yes

DHS 2002 data from Vietnam. All estimates control for region of Vietnam (North Uplands, Red River Delta, North Central, Central Coast, Central Highlands, South East, Mekong River Delta). Sample includes women with children. Sample weights employed. *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors are robust.

Table 10: Household formation rules and under-5 mortality of first-born children in Vietnam

PANEL A: Dep. var. is under-5 mortality of first-borns, women aged 15-49						
first-born male	0.0112*	0.0116*	0.0114*	0.0115*	0.0114*	0.0114*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
matri.*first born male	0.0832***	0.0822***	0.0810***	0.0784***	0.0783***	0.0787***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
matrilocal/matrilineal ethnicity	-0.0100	-0.0110	-0.0040	-0.0486	-0.0484	0.0000
	(0.015)	(0.015)	(0.015)	(0.061)	(0.061)	(0.000)
age	0.0018***	0.0019***	0.0019***	0.0018***	0.0018***	0.0018***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
completed higher ed.	-0.0463***	-0.0306***	-0.0299***	-0.0299***	-0.0295***	-0.0292***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
completed high school	-0.0109	-0.0071	-0.0059	-0.0059	-0.0057	-0.0055
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
adj.-R^2	0.02	0.02	0.02	0.02	0.02	0.02
No. obs.	5390	5390	5388	5388	5388	5388
Controls:						
rural	no	yes	yes	yes	yes	yes
religion	no	no	yes	yes	yes	yes
ethnicity*age interaction	no	no	no	yes	yes	yes
rural*region interaction	no	no	no	no	yes	yes
religion*ethnicity interaction	no	no	no	no	no	yes
PANEL B: Dep. var. is under-5 mortality of first-borns, women aged 40-49						
first-born male	-0.0051	-0.0046	-0.0055	-0.0055	-0.0055	-0.0052
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
matri.*first born male	0.1585**	0.1577**	0.1607**	0.1571**	0.1576**	0.1672**
	(0.063)	(0.063)	(0.064)	(0.068)	(0.068)	(0.070)
matrilocal/matrilineal ethnicity	-0.0461*	-0.0470*	-0.0344	-0.1440	-0.1408	-0.1160
	(0.025)	(0.025)	(0.026)	(0.644)	(0.646)	(0.674)
age	-0.0011	-0.0010	-0.0008	-0.0010	-0.0010	-0.0010
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
completed higher ed.	-0.0565***	-0.0469***	-0.0452***	-0.0455***	-0.0460***	-0.0461***
	(0.013)	(0.014)	(0.014)	(0.014)	(0.015)	(0.015)
completed high school	-0.0172	-0.0144	-0.0121	-0.0124	-0.0120	-0.0130
	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
adj.-R^2	0.02	0.02	0.02	0.02	0.02	0.02
No. obs.	1850	1850	1850	1850	1850	1850
rural	no	yes	yes	yes	yes	yes
religion	no	no	yes	yes	yes	yes
ethnicity*age interaction	no	no	no	yes	yes	yes
rural*region interaction	no	no	no	no	yes	yes
religion*ethnicity interaction	no	no	no	no	no	yes

DHS V data from Vietnam. All estimates control for region of Vietnam (North Uplands, Red River Delta, North Central, Central Coast, Central Highlands, South East, Mekong River Delta). Sample includes women with children. Sample weights employed. *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors are robust.

Table 11: Geology and the impact of male first-borns on under-5 mortality in Vietnam

	(1)	(2)	(3)	(4)	(5)
PANEL A: Dep. var. is total number is under-5 mortality of first borns, women aged 15-49					
first-born male	0.0126*	0.0125*	0.0123*	0.0124*	0.0089
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
first-born male*LOWQ	0.0321*	0.0323*	0.0314*	0.0316*	0.0142
	(0.019)	(0.019)	(0.019)	(0.019)	(0.018)
LOWQ	-0.0003	0.0013	-0.0074	-0.0071	0.0020
	(0.010)	(0.010)	(0.011)	(0.011)	(0.011)
age	0.0017***	0.0017***	0.0018***	0.0018***	0.0018***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
completed higher ed.	-0.0544***	-0.0529***	-0.0467***	-0.0467***	-0.0467***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
completed high school	-0.0195***	-0.0183***	-0.0123*	-0.0124*	-0.0124*
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
matri.*first born male					0.0754**
					(0.030)
adj.-R^2	0.01	0.01	0.01	0.01	0.02
No. obs.	5390	5388	5388	5388	5388
Controls:					
religion	no	yes	yes	yes	yes
matrilocal	no	no	yes	yes	yes
matri*religion	no	no	no	yes	yes
PANEL B: Dep. var. is under-5 mortality of first borns, women aged 40-49					
first-born male	0.0031	0.0021	0.0008	0.0005	-0.0058
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
first-born male*LOWQ	0.0239	0.0258	0.0253	0.0310	0.0014
	(0.035)	(0.035)	(0.035)	(0.036)	(0.036)
LOWQ	0.0002	0.0033	-0.0080	-0.0066	0.0114
	(0.021)	(0.021)	(0.024)	(0.025)	(0.025)
age	-0.0011	-0.0009	-0.0005	-0.0005	-0.0010
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
completed higher ed.	-0.0695***	-0.0646***	-0.0565***	-0.0565***	-0.0571***
	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)
completed high school	-0.0343***	-0.0300**	-0.0218	-0.0223*	-0.0232*
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
matri.*first born male					0.1728***
					(0.065)
adj.-R^2	0.01	0.01	0.01	0.01	0.02
No. obs.	1850	1850	1850	1850	1850
Controls:					
religion	no	yes	yes	yes	yes
matrilocal	no	no	yes	yes	yes
matri*religion	no	no	no	yes	yes

DHS 2002 data from Vietnam. All estimates control for region of Vietnam (North Uplands, Red River Delta, North Central, Central Coast, Central Highlands, South East, Mekong River Delta). Sample includes women with children. Sample weights employed. *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors are robust.

Table 12: Household structure in the DHS Surveys

	Patrilocality Index: Fraction of married women,15-30, who live with their father-in-law	Matrilocality Index: Fraction of married women,15-30, who live with their father	Employment rate of women, 15-49
1. Armenia	0.705	0.055	0.133
2. Albania	0.635	0.026	0.211
3. Azerbaijan	0.577	0.040	0.114
4. Vietnam	**0.403**	**0.094**	**0.845**
5. Pakistan	0.379	0.062	0.247
6. Nepal	0.369	0.074	0.690
7. Swaziland	0.335	0.049	0.396
8. India	0.322	0.103	0.294
9. Senegal	0.312	0.093	0.381
10. Morocco	0.288	0.049	0.141
11. Maldives	0.288	0.368	0.333
12. Turkey	0.252	0.024	0.216
13. Lesotho	0.245	0.111	0.373
14. Ukraine	0.191	0.237	0.640
15. Egypt	0.187	0.049	0.123
16. Afghanistan	0.180	0.020	-
17. Bangladesh	0.176	0.126	0.265
18. Moldova	0.164	0.165	0.421
19. Guyana	0.148	0.111	0.279
20. Niger	0.132	0.028	0.390
21. Zimbabwe	0.129	0.052	0.354
22. Tanzania	0.121	0.037	0.867
23. Philippines	0.120	0.144	0.393
24. Indonesia	0.108	0.212	0.452
25. Timor l'Este	0.107	0.156	0.389
26. Nicaragua	0.102	0.122	0.326
27. Guinea	0.091	0.058	0.853
28. Kenya	0.082	0.019	0.601
29. Côte d'Ivoire	0.082	0.056	0.680
30. Honduras	0.073	0.073	0.333
31. Jordan	0.070	0.047	0.115
32. Cambodia	0.069	0.198	0.592
33. Peru	0.066	0.138	0.598
34. Sierra Leone	0.064	0.085	0.765
35. Liberia	0.061	0.084	0.641
36. Cameroon	0.056	0.041	0.688
37. Benin	0.056	0.037	0.265
38. Colombia	0.051	0.096	0.438
39. Haïti	0.049	0.146	0.498
40. Gabon	0.049	0.040	0.386
41. Madagascar	0.049	0.035	0.913
42. Congo Brazzaville	0.046	0.045	0.664
43. Bolivia	0.043	0.066	0.607
44. Dominican Republic	0.041	0.117	0.352
45. Congo (DR)	0.041	0.055	0.732
46. Uganda	0.037	0.020	0.877
47. Namibia	0.036	0.049	0.445
48. Burkina Faso	0.033	0.013	0.774
49. Ethiopia	0.028	0.019	0.232
50. Nigeria	0.027	0.027	0.653
51. Ghana	0.025	0.061	0.870
52. Mali	0.023	0.029	0.626
53. Malawi	0.018	0.044	0.576
54. Zambia	0.016	0.044	0.500
55. Chad	0.015	0.058	0.767
56. Rwanda	0.003	0.007	0.717
57. Burundi	0.003	0.006	0.825
58. São Tomé and Príncipe	0.000	0.186	0.537

Figure 1: Matrilocality ethnicity incidence by district, Vietnam 1999 IPUMS census microdata sample

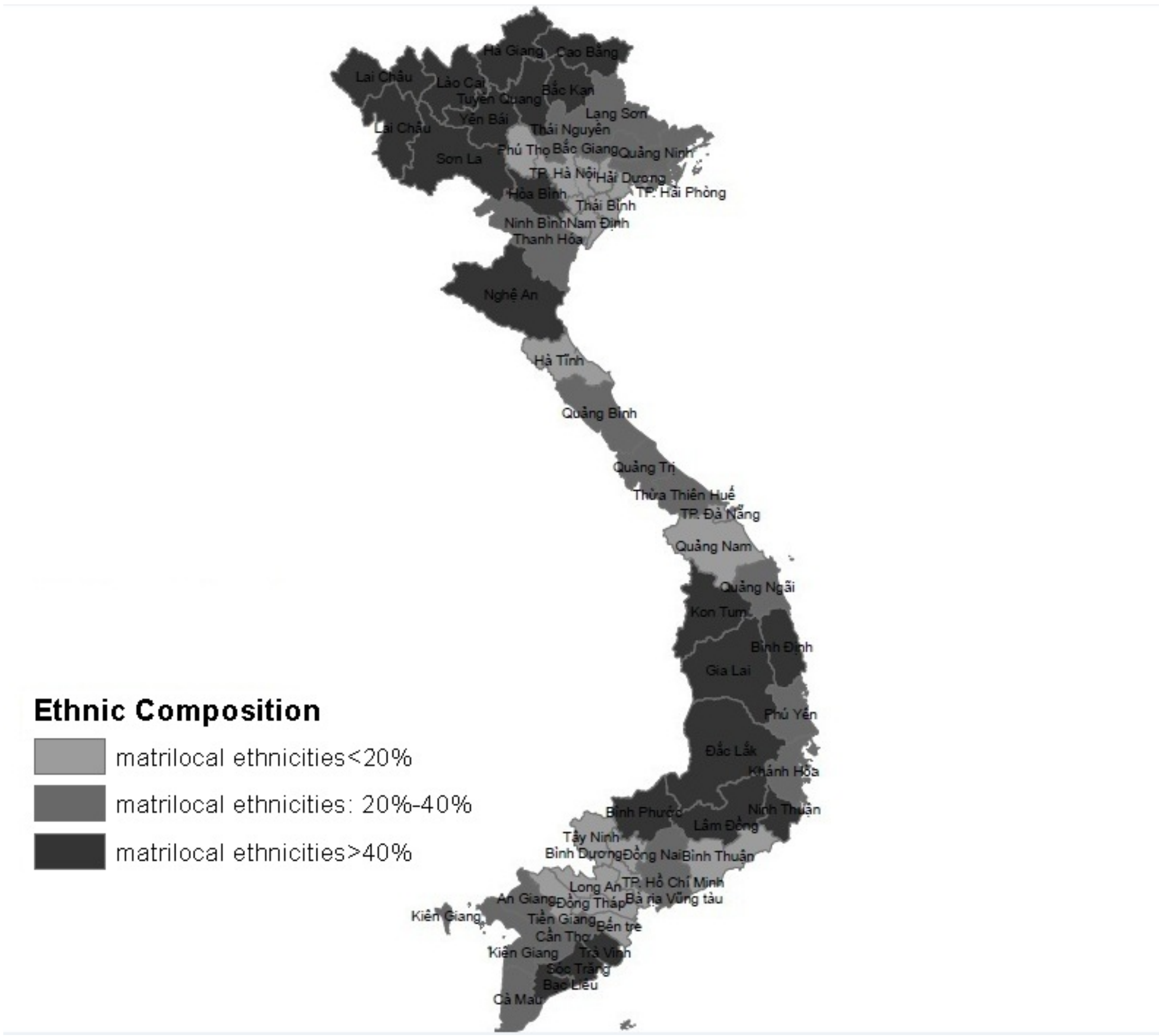


Figure 2: Land slope in Vietnam

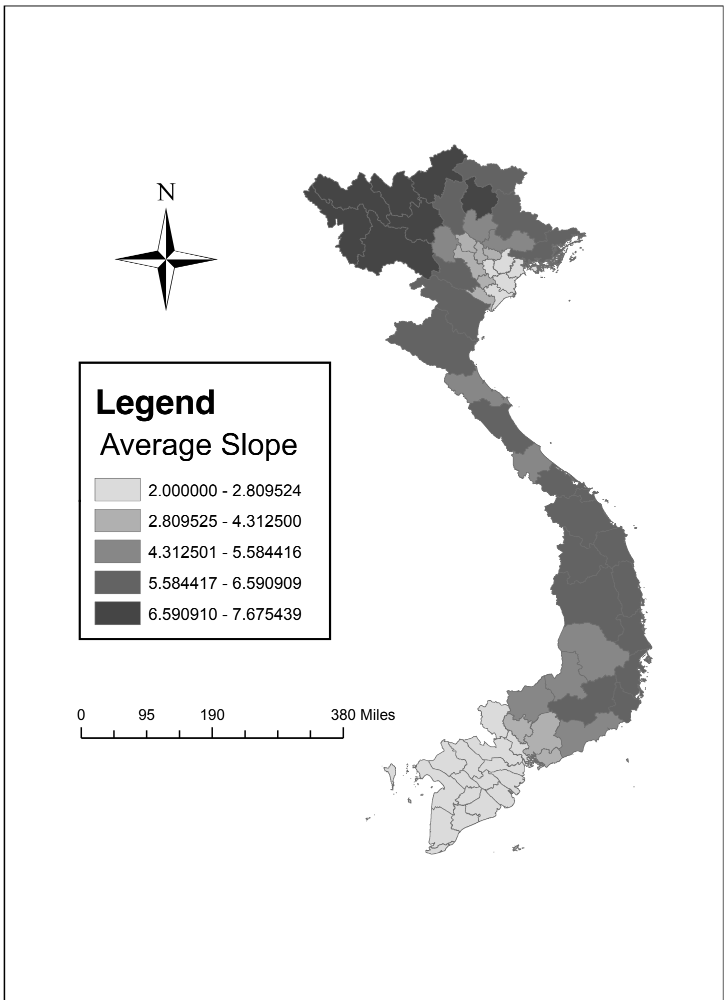


Figure 3: Female employment and differences in fertility at age 40-49, DHS.
Mean(first-born female)-mean(first-born male)

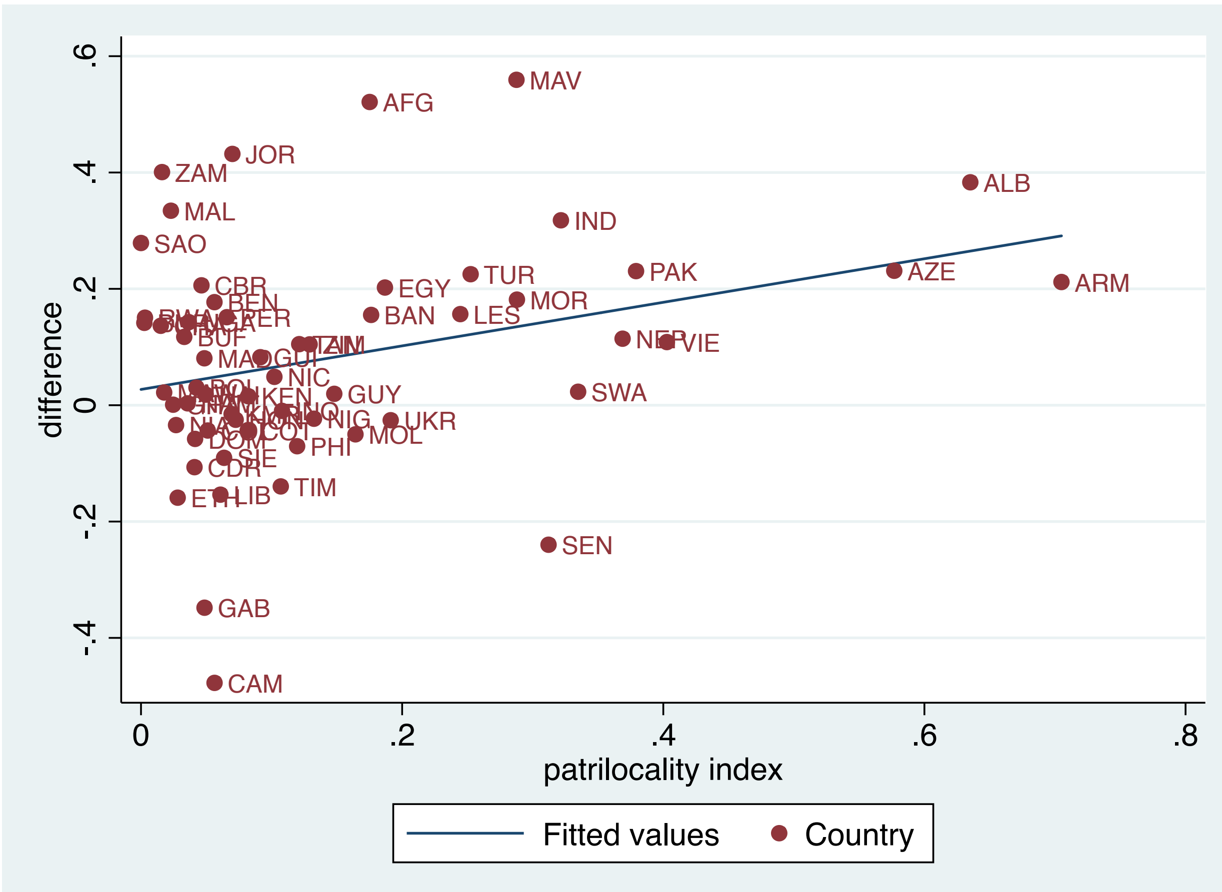
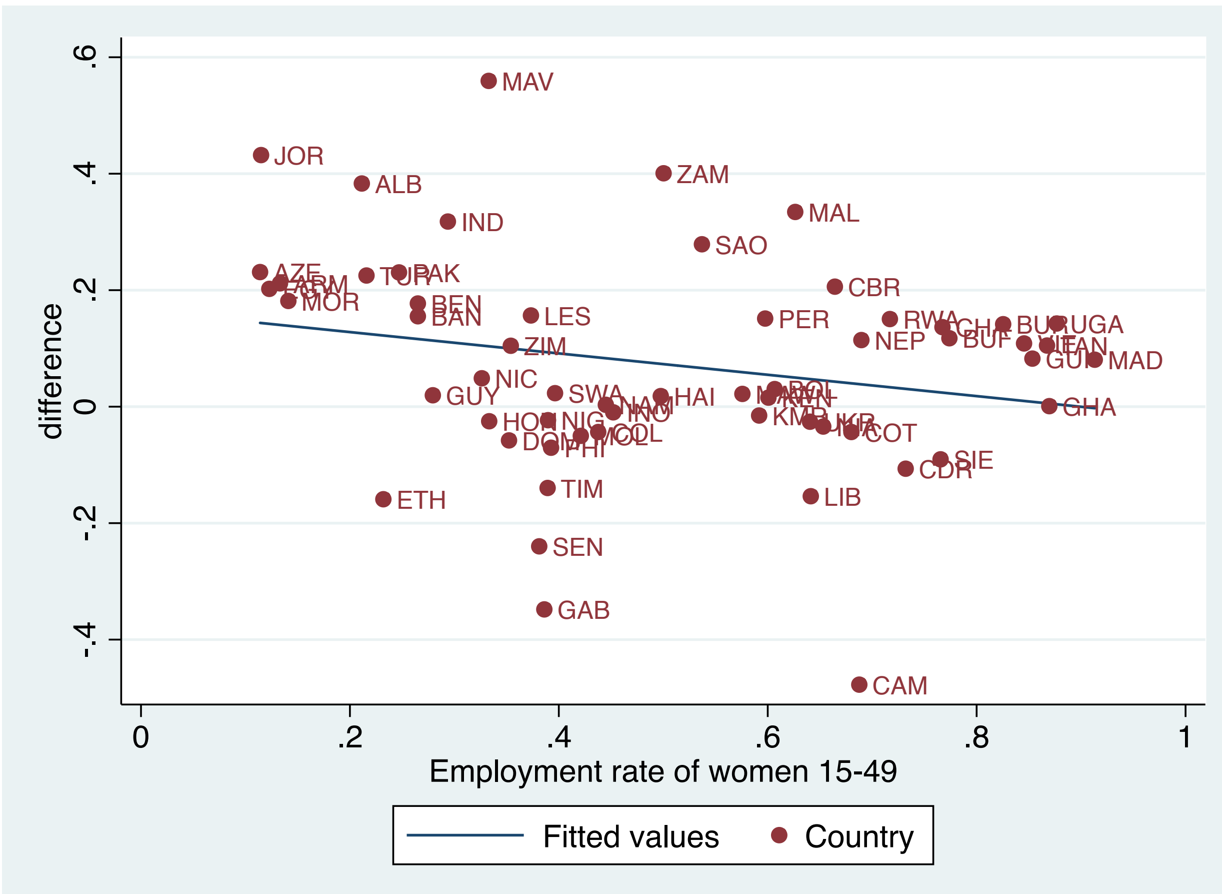


Figure 4: Female employment and differences in fertility at age 40-49, DHS.
Mean(first-born female)-mean(first-born male)



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